DESIGN AND INSTALLATION
OF
ULTRA HIGH-SPEED DELUGE SYSTEMS

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DESIGN and INSTALLATION of ULTRA HIGH-SPEED DELUGE SYSTEMS
for
ORDNANCE FACILITIES

I. Introduction:

1. The design and installation of ultra high-speed deluge systems for ammunition applications involves a technology which is substantially different from that associated with automatic sprinkler systems. Because, due the speed of water delivery from all of the nozzles, ultra high-speed deluge systems are highly dependent on the detection system, piping network, nozzles, and water supply characteristics, the design and the installation of ultra high-speed deluge systems must be performed by experienced designers and installers who thoroughly understand the limitations and capabilities of these systems.

2. Ultra high-speed deluge systems are sometimes installed with no thought or knowledge as to the hazards that they are to protect. Often, the system is designed or procured around specifications written for a completely different process. The lack of a complete definition of response time also effects the design of ultra high-speed deluge system.

3. This paper will discuss the following points:

a. Brief description of an ultra high speed deluge system.

b. Justification for ultra high-speed deluge systems.

c. Proposed change to the definition of response time.

d. Factors effecting water travel time from the nozzle to hazard.

e. Changes to deluge system regulation.

II. The System.

1. Ultra high-speed deluge systems are used to protect personnel, process equipment, and buildings from the fire and thermal hazards presented by munition handling operations such as weighing, pressing, pelletizing, propellant loading, melting, extrusion, mixing, blending, screening, sawing, granulating, drying, and pouring. An ultra high-speed deluge system is designed to respond in ms by detecting a flame or ignition source in its incipient stage and by applying large volumes of water. A pre-primed, ultra high-speed deluge system utilizes the components listed below:

- Flame detector ultraviolet (UV) or infrared (IR)).

- Electronic controller (microprocessor).

- Valve (squib or solenoid operated).

- Pre-primed piping system with nozzles.

- Water supply.

2. See Appendix C for additional details.

III. Justification.

1. Ultra high-speed suppression has proven effective in prevention of propagation. For instance, during an explosive loading operation, the projectile being loaded initiated, and the deluge system was able to prevent propagation of the main explosive hopper. In cases of personal protection, there have been many cases where operators have been doused by water and serious burns were prevented. Total extinguishment has been accomplished many times in past incidents. Depending on the cost of the equipment, even if it is a remote operation, savings can be substantial if the fire is extinguished or not allowed to propagate.

2. The United States Department of Defense Ammunition and Explosives Safety Standards (DOD 6055.9-STD) states that, where exposed thermally energetic materials are handled that have a high probability of ignition and a large thermal output as indicated by a hazard analysis, they must be protected with an ultra high-speed deluge system. The system must suppress potential fires in their incipient state. Other publications such as AMCR 385-100 (U.S. Army Materiel Command Safety Manual), Navy Sea System Command OP 5 (Ammunition and Explosives Ashore), DOD 4145.26M (Contractor's Safety Manual), Military Handbook 1008 (Fire Protection for Facilities Engineering, Design, and Construction), and the National Fire Codes also provide guidance on ultra high-speed deluge systems.

3. Change 1 to AMCR 385-100 has clearly defined when a deluge system is required. An ultra high-speed deluge system is required when a potential fire and/or thermal hazard has a risk assessment code (RAC) of 1 or 2, as defined in AR 385-10, The Army Safety Program. See Figure 1.

IV. Response Time.

1. Response time criteria should be realistic and defined in a manner that will permit meaningful testing of the completed installation to ensure the performance criteria are met. There has been no common agreement on the definition of deluge system response time. This has caused confusion and prevented the development of a performance-type specification. This precludes the effective evaluation of ultra high-speed deluge systems.

2. In order to more precisely define response time requirements, it is necessary to understand the interrelationship between development of an incident and deluge system functions. The following outlines a way of breaking down the fire dynamics and deluge system functions into understandable segments:

a. Ignition Time T0: The start of ignition. Ignition of an item is defined as self-sustained deflagration.

b. Ignition To Sensing Threshold Time T1: The time from ignition until the buildup of energy reaches the sensing threshold of the detector saturation. This is dependent upon the configuration of the item being protected. For example, the ignition of propellant from the bottom of a hopper may require more than a second to reach the surface of the propellant where it can be sensed by a detector. If ignition occurred on the surface, the ignition to sensing threshold period would be in the ms range.

c. Ignition To Detector Response Time T2: The time from ignition to transmission of the signal to the controller.

d. Ignition To Controller Response Time T3: The time from ignition to transmission of signal to deluge valve squib or solenoid.

e. Ignition To Valve Opening Time T4: The time from ignition to the opening of the deluge valve permitting water to flow.

f. Ignition To First Water at the Nozzle Time T5: The time from ignition to the first flow of water from the critical nozzle(s). This is usually the nozzle(s) closest to the hazard or as determined by a hazard analysis.

g. Ignition To First Water on Target Time T6: The time from ignition to the first drops of water to strike the target from the critical nozzle(s). There is usually an initial stream of water, followed by a break in the flow, followed by a full flow pattern.

h. Ignition To Full Flow Water On Target Time T7: The time from ignition to a fully-developed spray of water strikes the target area.

i. Extinguishment Time T8: The time from ignition to termination of the deflagration.

3. There is no universally accepted agreement on the definition of deluge system response time time. DOD 6055.9-STD, Ammunition and Explosives Safety Standards, and NAVSEA OP 5 Volume 1, Ammunition and Explosives Ashore, Safety Regulations for Handling, Storing, Production, Renovation, and Shipping discuss deluge systems but provide no guidance on response time. MIL-HDBK-1008A, Fire Protection for Facilities Engineering, Design, and Construction, cites a response time of 0.5 seconds (500 ms) but does not define response time. The U.S. Army Materiel Command Safety Manual, AMCR 385-100, provides the most complete definition of response time. It defines the response time for ultra high-speed deluge systems as: The sensing of a detectable event by the detector to the beginning of water flow from the critical nozzle(s) closest to the hazard or as determined by the hazard analysis (T1-T4). In lieu of testing, a small deluge system (design flow rate of 500 GPM or less) shall have a response time of 100 ms and large deluge system (design flow rate of more than 500 GPM) shall have a response time of 200 ms.

4. This definition does not consider the time required for the water to travel from the nozzles to the hazard being protected. This is the forgotten factor in the design of ultra high-speed deluge systems. It is not uncommon to see deluge systems that are specified for 100 ms response time, installed with nozzles 14 feet above the hazard. Applications like this are a waste of effort and provide an ineffective, unsafe system. The high-speed video tapes of the portable deluge tests at Tooele Army Depot and and other tests conducted at various Army ammunition plants (AAPs) very graphically show the need to measure not only the time from detection to water at the nozzle but also from the nozzle to the target (hazard).

5. Deluge system response time should be redefined as total response time. This is the total time lapse from detector sensing threshold response to full flow of water on the target area (T1-T7). Total response time consists of two segments, detection time (T1-T4) and water delivery time (T4-T7). Detection time is the time from detector sensing threshold of the fire to the time that the signal is amplified and fires the primer in the water control valve or opens the solenoid valve (T1-T4). Water delivery time is the time required from primer firing or solenoid valve opening to the time a fully developed spray of water strikes the target (T4-T7). These will be discussed in more detail below.

6. Proposed definition: Response time is defined as the time from the sensing of a detectable event by the detector to a fully-developed spray of water striking the target/hazard from the critical nozzle(s) closest to the hazard or as determined by the hazard analysis. In lieu of testing, a small deluge system (design flow rate of 500 GPM or less) shall have a response time of XXX ms and large deluge system (design flow rate of more than 500 GPM) shall have a response time of YYY ms(T1-T7).

7. The actual times will need to be determined by testing and experience.

8. The total response time must be considered when designing deluge systems. The use of total response time provides a means to realistically evaluate the required response time of deluge systems. This will also provide a baseline for checking system response time during the annual flow tests and after a system has been inactive for an extended period of time, or a system has been modified.

V. Factors That Effect Water Travel Time.

1. Detection time is the time from detector sensing threshold of the fire to the time that the signal is amplified and fires the primer in the water control valve or opens the solenoid valve (T1-T4). The detection time is the fastest phase, and under ideal conditions, can be accomplished in as little as 10 ms. Although it is possible to shorten the detection time, the cost and increased chances of false activations usually make this impractical. Factors effecting detection time include:

a. Distance between detector and target.

b. Type of flame and amount of smoke.

c. Signal processing time.

d. Detector sensitivity.

2. Water delivery time is the time required from primer firing or solenoid valve opening to the time a fully developed spray of water strikes the target (T4-T7). It is the most time consuming portion of total response time. It is also the easiest to reduce both in terms of cost and system reliability. Water delivery time is dependent on several factors:

a. Water pressure.

b. The distance between the nozzle and hazard.

c. Type of nozzle and piping configuration.

d. The completeness of water prime of the piping system from the valve to the nozzles.

3. Research conducted by various agencies in the DOD establishment and private sector indicates there is a direct relationship between water travel time, water pressure, and nozzle type.

a. Preliminary tests at one facility indicated a definite relationship between pressure, water travel distance, and type of nozzle. With a target 12 inches from a nozzle, increasing the pressure from 75 to 150 psi resulted in a decrease of 13 ms (55 to 43 ms) for Nozzle A. The corresponding values for Nozzle B and C were 9 ms (46 to 37 ms) and 9 ms (56 to 47 ms) respectively. This pressure response relationship becomes more pronounced as the distance from the nozzle to the target is increased. With a target 36 inches from a nozzle, increasing the pressure from 75 to 150 psi resulted in a decrease of 20 ms (93 to 73 ms) for Nozzle A. The corresponding values for Nozzle B and C were 12 ms (91 to 79 ms) and 25 ms (116 to 91 ms) respectively. Figure 1 shows this relationship. While these distance/pressure relationships can vary somewhat depending on the type of nozzle and the basic relationship hold true for all systems. As can be seen by Figure 2 the difference in response times between the nozzles becomes greater as the pressure is increased.

b. Portable deluge tests conducted at Tooele Army Depot in March 1988 indicated there was a definite relationship between distance, pressure, and the type of nozzle. This relationship was observed during a review in the high speed video tape taken of the tests.

c. Several demonstrations at the 1984 Automatic Sprinkler Corporation Deluge Seminar indicated the following:

(1) The response times at 100 psi were approximately 20 ms faster than at 50 psi for both the squib and pilot types of systems. A pilot system was also tested twice at 150 psi. Surprisingly, the response times were the same as at 100 psi.

(2) A pilot system was activated four times, and the response times measured with a high-speed video camera. Detection time averaged 97 ms and water travel time from the nozzle to the target averaged 39 ms. The travel distances ranged from 15 inches to 24 inches. While four tests are not statistically valid, they provide an indication. See Figure 3.

d. Some tests done at Lone Star AAP in mid 1970's had similar results. A pilot type system was used with the nozzles set approximately 18 inches from the target. Tests were run at 75 and 100 psi. Water travel time was approximately 20 ms faster at the higher pressure. The type of nozzle also effected the water travel time.

4. Other items that can improve response time of systems.

a. Lone Star AAP:

(1) Lone Star AAP, operated by Day & Zimmermann Inc., has been a leader in the design of ultra high-speed deluge systems. For example, during the performance testing of two deluge systems, the design target of 100 ms could not be met. After analyzing the problem, three engineering changes were made: a looped water supply piping system in each bay; installation of a small pressurized surge tank; and removal of multiple 90-degree elbows. The response time was significantly reduced.

(2) A limited number of tests was conducted, and there was a problem with of erratic data caused by debris in system piping. This limits the credibility of test results; however, a reduction in response times of up to 60 percent indicated a need for more evaluation of the three design concepts for improved response times on ultra high-speed deluge systems.

(3) In one bay, the measured response time of a critical nozzle was reduced incrementally from 179 ms to 71 ms with the installation of the three modifications. That is a response time reduction of 60 percent. In another bay, a critical nozzle response time was improved from 124 to 70 ms after multiple 90-degree elbows were removed from the water supply line; however, the increase in response time of another critical nozzle from 109 to 225 ms indicates a possible problem with debris in the lines. After the looped pipe was installed, trash was found in the system. The trash was removed; however, the response time of 129 ms was still unacceptable. After installation of the surge tank, the response time of the critical nozzle dropped to 69 ms, which was acceptable. The surge tank had a capacity of 2 to 5 gallons. The tank was a standard bladder water pressure tank pressurized to approximately 26 psi. See figure 3. NOTE: All response times are detection to water at the nozzle.

(4) The general pattern of incremental reductions in response as each of the three modifications were completed indicates a need for further evaluation of the merits of looping the piping, installing the surge tanks, and removing the 90-degree elbows.

(5) The tests also indicate that trash and scale in deluge system piping can effect response time. This will become more of a problem as the water supply systems at ordnance facilities age. Many of these systems are more than 40 years old.

b. Research and experience have demonstrated the importance of removing all air trapped in the piping system of Primac Systems. An air pocket constituting 5 percent of the total volume of the system can cause a 100 percent increase in response time. An undetected small leak could result in the loss of water and entrance of air into the piping system which could drastically slow the system response time. One installation is evaluating a system for automatically removing trapped air and automatically adding water to the piping system whenever required.

VI. Changes to Deluge System Regulations.

1. The section on ultra high-speed deluge systems in AMCR 385-100 has been completely revised. The changes appear in Chapter 12 of Change 1, dated 16 March 1990. See Appendix 4 for details. The major changes include:

a. A potential fire and/or thermal hazard whose level of risk (RAC 1 or 2) is unacceptable will be mitigated by ultra high-speed deluge system, unless such a system will aggravate the hazard (reference AR 385-10 and AMCR 385-3).

b. Deluge systems will have a response time of 100 ms for small systems (design flow of 500 GPM or less) and 200 ms for large systems (design flow of more than 500 GPM).

c. Response time is defined as the time from the sensing of a detectable event by the detector (detector input) to the beginning of water flow from the critical nozzles.

d. Deluge systems shall be tested IAW the criteria of TM 5-695. Systems in laid-away or inactive facilities are exempt; however, they will be tested when put back into service. Records of the tests should be be kept on file at the installation.

(1) A full operational flow test shall be conducted at intervals not to exceed 1 year, including measurement of response time. The results of the tests, or the use of the 100 or 200 ms response time will be retained on file by the installation for the life of the system.

(2) Detectors shall be tested and inspected for physical damage and accumulation of deposits on the lenses at least monthly.

(3) Controllers will be checked at the start of each shift for any faulty readings.

(4) Valves on the water supply line shall be checked at the start of each shift to ensure they are open.

e. Melt kettles and closed containers of molten explosives do not normally require the use of internal detectors or nozzles.

2. The AMCCOM Safety Office has submitted a completely new section on fire protection operations for ordnance operation and facilities for inclusion in the next revision of MIL-HDBK 1008. A copy is provided in Appendix E.

VII. Summary:

1. This paper provides an update on issues effecting the design and installation of ultra high-speed deluge systems. They include:

a. The need to redefine response time to include water travel time from the nozzle to the hazard.

b. Several ways that can improve system response time.

c. Changes to deluge system regulations.

2. Questions should be directed to Mr. Robert Loyd, U.S. Army Armament, Munitions and Chemical Command, ATTN: AMSMC-SFP, Rock Island, IL 61299-6000. Telephone: commercial (309) 782-2975/2182 and DSN 793-2975/2182.

VIII. Acknowledgment.

1. The technical reports in appendix A and the references in appendix B were utilized in the preparation of this paper.

2. The author greatly appreciates the technical assistance and material provided by the individuals below:

a. Mr. Gene Burns, Day and Zimmermann, Inc., Lone Star AAP.

b. Mr. Gary Fadorsen, Pyrotech International (formerly with Automatic Sprinkler Corporation).

c. Mr. Joe Priest, Grinnell Fire Protection.

d. Mr. Ken Klapmeier, Detector Electronics.

RISK ASSESSMENT CODE

	Accident Probability			
Hazard Severity	A	B	C	D
I	1	1	2	3
II	1	2	3	4
III	2	3	4	5
IV	3	4	5	5

<u>Accident Probability</u>

Description: Frequent
Level: A

Description: Probable
Level: B

Description: Occasional
Level: C

Description: Remote
Level: D

<u>Hazard Severity</u>

Catagory: 1
Description: Catastrophic

Category: II
Description: Critical

Catagory: III
Description: Marginal

Catagory: IV
Description: Negligible

FIGURE 1

AVE. RESPONSE TIMES FROM NOZZLE AT DIFFERENT DISTANCES

Distance from Nozzle to Target	12"	36"
75 p.s.i. NOZZLE		
A 40 degrees	55"	93"
B 90 degrees	46"	91"
C 120 degrees	56"	116"
125 p.s.i. NOZZLE		
A 40 degrees	44"	75"
B 90 degrees	41"	80"
C 120 degrees	48"	93"
150 p.s.i. NOZZLE		
A 40 degrees	43"	73"
B 90 degrees	37"	79"
C 120 degrees	47"	91"

Response Time (millisecounds)

FIGURE 2

EXAMPLES OF TOTAL RESPONSE TIME

TEST#	PRESSURE	WATER TRAVEL DISTANCE	DETECTION TIME		WATER TRAVEL TIME		TOTAL TIME
1	50 psi	18 in.	116 ms	+	41 ms	=	157 ms
2	175 psi	15 in.	91 ms	+	33 ms	=	124 ms
3	175 psi	21 in.	99 ms	+	41 ms	=	140 ms
4	175 psi	24 in.	91 ms	+	41 ms	=	132 ms

FIGURE 3

2111

DESIGN IMPROVEMENTS

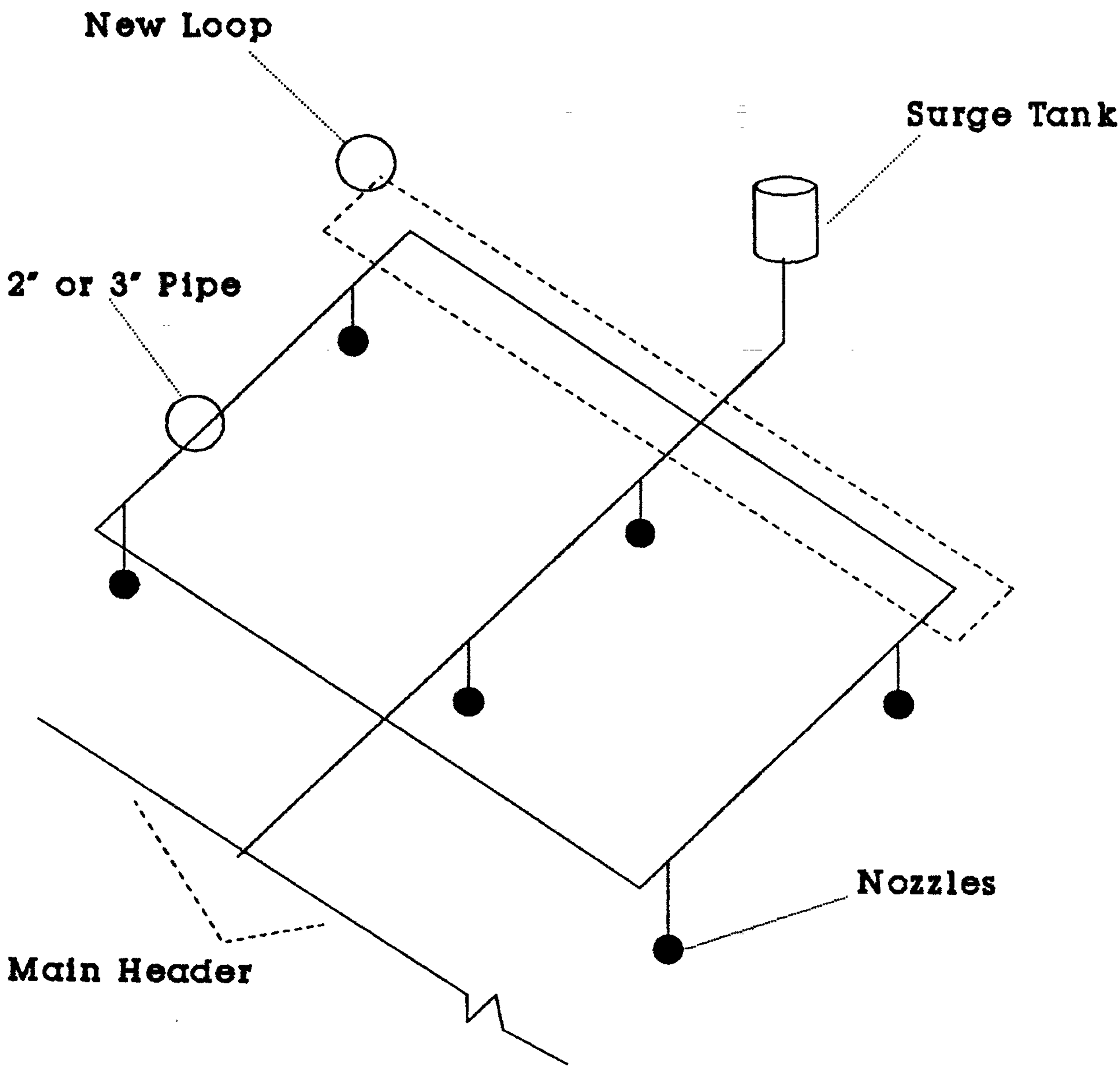

FIGURE 4

APPENDIX A

APPENDIX A

TECHNICAL REPORTS ON DELUGE SYSTEMS

1. Design of a Deluge System to Extinguish Lead Azide Fires, No. AD-E400 204, Aug 78, approved for public release (APR).

2. Evaluation of Pyrotechnic Fire Suppression System for Six Pyrotechnic Compositions, No. AD-E401 306, Mar 85, APR.

3. Engineering Guide for Fire Protection and Detection Systems at Army Ammunition Plants, Vol I (Selection and design), No. AD-E400 531, Dec 80, APR.

4. Engineering Guide for Fire Protection and Detection Systems at Army Ammunition Plants, Vol II (Testing & Inspection), No. AD-E400 874, Dec 82, Distribution limited to U.S. Government Agencies only - contains proprietary information.

5. On-site Survey and Analysis of Pyrotechnic Mixer Bays, No. AD-E401 141, Feb 84, APR.

6. Feasibility Study to Develop a Water Deluge System for Conveyor Lines Transporting High Explosives, Tech Rpt No. 4889, Aug 75, APR.

7. Development of a Water Deluge System to Extinguish M-1 Propellant Fires, No. AD-E400 217, Sep 78, APR.

8. Design of a Water Deluge System to Extinguish M-1 Propellant Fires in Closed Conveyors, No. AD-E400 216, Sep 78, APR.

9. Fire Suppression System Safety Evaluation, No. AD-E401 083, Dec 83, APR.

10. Dynamic Model of Water Deluge System for Propellant Fires, No. AD-E400 315, May 79, APR.

11. Deluge Systems in Army Ammunition Plants, prepared by Science Applications, Inc., for the U.S. Army Munitions Production Base Modernization Agency, 30 Jun 81.

12. Minutes of the Rapid Action Fire Protection System Seminar, U.S. Army Armament, Munitions and Chemical Command, 23-24 Oct 84.

13. Water Deluge Fire Protection System for Conveyor Lines Transporting High Explosives, No. AD-E400 034, Dec 77, APR.

14. Evaluation of an Improved Fire Suppression System for Pyrotechnic Mixes, No. AD-E401 569, Sep 86, Distribution limited to U.S. Goverment Agencies only.

15. Analysis of Mixer Bay Designs for Pyrotechnic Operations, No. AD-E401 602, Nov 86, APR.

16. Calculating Sprinkler Actuation Time in Compartments, Center for Fire Research, National Bureau of Standards, Mar 84.

17. Guidelines for a Thermochemical Kinetics Computer Program, Los Alamos National Laboratory, LA-10361-MS, May 85.

18. Mathematical and Numerical Methods Used in Thermal Hazards Evaluation, Naval Weapons Center China Lake, NWC TP 6510, Dec 86.

19. Technical Report on the Testing of Ultraviolet Actuated Deluge Systems Utilizing Solid State Controllers and Detonator-Actuated Valves to Extinguish Black Powder Fires, Day and Zimmerman, Lone Star Division, Nov 86.

20. Hazel - "A Computerized Approach to System Safety," Ken Proper, U.S. Army Defense Ammunition Center and School, Equipment Div, Aug 86.

Most of these reports can be ordered from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22314. Their telephone number is AV 284-7633.

APPENDIX B

APPENDIX B

REFERENCES

1. AMC Safety Manual, AMCR 385-100, 1 Aug 85.

2. DOD Ammunition and Explosives Safety Standards, DOD 6055.9-STD, Jul 84.

3. Maintenance of Fire Protection Systems, TM 5-695 (Army)/FAC MO-117 (Navy)/ AFM 91-37 (Air Force), Oct 81 with Change No. 1.

4. Military Handbook - Fire Protection for Facilities Engineering, Design, and Construction, MIL-HDBK-1008, 30 Apr 85.

5. National Fire Codes, National Fire Protection Association.

APPENDIX C

APPENDIX C

COMPONENTS OF AN ULTRA HIGH-SPEED DELUGE SYSTEM

I. Introduction.

1. Ultra high-speed deluge systems are used to protect personnel, process equipment, and buildings from the fire and thermal hazards presented by munition handling operations such as weighing, pressing, palletizing, propellant loading, melting, extrusion, mixing, blending, screening, sawing, granulating, drying, and pouring. An ultra high-speed deluge system is designed to respond in milliseconds by detecting a flame or ignition source in its incipient stage and by applying large volumes of water. A preprimed, ultra high-speed deluge system utilizes the following components:

- Flame detector (ultraviolet (UV) or infrared (IR)).
- Electronic controller (microprocessor).
- Valve (squib or solenoid operated).
- Preprimed piping system with nozzles.
- Water supply.

2. When a flame detector senses the radiant energy of a flame or ignition source within its field of coverage, it will respond within milliseconds, sending a signal to the electronic controller. The controller, in turn, sends a signal to the valve to open. Opening of the valve permits supply line water pressure to be applied to the priming water already in the pipe between the valve and the nozzles, causing water to flow from the nozzles suppressing the fire. At the same time, signals are sent to operate alarms and shut down process equipment. Approximately 500 preprimed, ultra high-speed deluge systems are used within the U.S. Army ammunition plant complex. We will discuss the components of an ultra high-speed deluge system in more detail later.

3. The ultra high-speed deluge system evolved from the conventional automatic sprinkler system. The conventional-type systems utilize closed heads with fusible links. It requires several minutes for the fusible links to melt and water to flow in the event of a fire. Next, came open head systems which were dependent upon heat actuated devices (HAD) to sense the fire and open a valve which permitted the water flow. Depending upon the HAD location, detection and water flow required 1 to 2 minutes. Finally, came the ultra high-speed deluge systems that use flame detectors (IR and UV), solid state electronic devices, explosively-actuated or solenoid-actuated valves, and the use of a preprimed piping system and nozzles to provide adequate water patterns and densities.

II. Detectors.

1. The flame detector is an optical device that responds to the radiant energy that is given off by a flame. When a flame or ignition source occurs within the field of view of the detector, the resulting electromagnetic radiation travels toward the detector at the speed of light. The detector responds to the radiant energy in milliseconds, sending a fire signal to the electronic controller.

2. The use of microprocessors now makes it possible to count and process the digital pulses from the UV detectors. Pulses no longer need to be stored in capacitors, but can be individually counted, entered into the registers of the microprocessor, stored in memory, and manipulated like any type of data processing information. This allows the design of flexible UV fire detectors using programmable memories and switches to provide an infinite number of combinations. Thus, we now have a marriage of UV detection devices with state-of-the-art microprocessors. Since the UV detector requires no signal processing other than comparing the radiation level to a present threshold, a very fast response time is achieved.

3. Ultraviolet detectors are ideally suited for applications where rapidly developing fires can occur in open areas. Ultraviolet detectors can be used to monitor ammunition assembly lines and renovation operations involving open mixing operation or open areas that are stocked with energetic materials awaiting processing. The UV detector is sensitive to welding arcs, lightning, gamma radiation, high electrostatic charges, and is easily obscured by contamination on the detector lens or in the atmosphere.

4. Typical applications for these high-speed IR detectors are characterized by strictly controlled, dark environments where a flash fire could originate. Conveyor belts passing through large covered ducts and closed explosive and propellant mixers are examples of the controlled environment necessary for proper application. However, high-speed IR sensors still must be carefully isolated from possible false alarm sources. Such sources include the sun and other blackbody radiation sources, high intensity light, flashbulbs, and fluorescent and incandescent lighting.

5. Typically, these systems are recommended to be used in combination with the appropriate UV systems, combining the advantages of UV for space protection with IR for enclosed areas. When dealing with an entire fire detection system that utilizes one or more than one type of detector, a detonator module greatly expands the flexibility and capability for the system. An individual detonator module can accept multiple input from UV and IR controllers, other detonator modules, manual alarm stations, heat sensors, smoke detectors, pressure sensors, or any contact closure device. In the event of a fire, any of these devices will cause the internal fire circuitry of the module to activate the detonator circuit, sound alarms, shut down process equipment, and identify the zone that detected the fire. When properly used, some detonator modules can add only a few milliseconds to the total system response time.

III. Valves.

1. Three types of ultra high-speed fire suppression systems are used in the U.S. Army ammunition plant/depot complex. They are the squib- actuated valve, the solenoid-actuated valve, and the explosive rupture valve.

2. The squib-operated valve uses an explosively-activated squib and a water-primed piping system in which, when the detection system senses the presence of radiant energy of an intensity and wavelength exceeding the detector's threshold, it sends an amplified electrical signal to the controller and detonator module which detonates the squib/primer in the control valve. The primer fires releasing a latch allowing the water supply line pressure to open the valve, thus, increasing the priming water pressure in the piping to the nozzle cap or rupture disk. The line pressure blows off the nozzle caps or bursts the rupture disk allowing water flow to the hazard.

3. The basic components of the solonoid-operated system are one or more IR or UV flame detectors, controller, pilot line solenoid, pilot control valve and nozzle, and supervisory test devices. In this system, the nozzle and associated valve is a pilot line-operated nozzle (relief) valve that is kept closed against the supply (fire) line pressure by the water pressure in the pilot line. This pilot line is normally connected to the water main as a source of pressure. The differential on the valve activating surface area (pilot line versus main water line pressure) maintains the nozzle valve in the closed position. The detector system may utilize IR or UV detectors. These detectors, upon responding to a fire, send an amplified signal to the controller, which, in turn, sends a signal to the pilot line solenoid-operated relief valve, causing it to open. This drops the pilot line pressure allowing the pilot control nozzle valves to open and main line water to flow. The pilot line is small enough to prevent the pilot pressure from being maintained with the relief valve in the open position. When pilot pressure is restored, the poppet reseats, even against fire main pressure.

4. A third type of ultra high-speed deluge system uses the explosive rupture disc. It has seen only limited use in the ammunition plant complex. It consists of preprimed piping with explosive rupture discs placed behind each nozzle. When a fire is detected, the squibs are fired, rupturing the disc, providing water at a very fast rate This system can be preprimed at a much higher pressure than the squib valve. This type of system has been used on ammunition peculiar equipment.

IV. Preprimed Piping System with Nozzles.

1. An air pocket constituting 5 percent of the total volume of the system can cause a 100 percent increase in response time. An undetected small leak could result in the loss of water and entrance of air into the piping system which could drastically slow the system response time.

2. The pipe diameter, length, number of bends, and friction coefficient contribute to the volume of water that can be transported at an effective

pressure through the piping system. Pipe runs and bends should be kept to a minimum, and all horizontal runs should be sloped at least 1/4 inch per 10 feet of run, with air bleeders at all high points.

V. Water Supply.

1. The water density required will depend upon the type, quantity, and configuration of energetic material involved, process layout, and whether the goal is extinguishment, prevention of propagation, prevention of injury, or a combination of these. A commonly used density for preventing propagation and structural damage is 0.5 GPM/sq ft. The protection of personnel and process equipment, as well as the extinguishment of pyrotechnic fires, requires significantly higher density rates. These may be as high 3.0 GPM/sq ft for area coverage or 50 GPM/nozzle for point of operation coverage. Tests have shown that fires involving some pyrotechnic materials being mixed require a water flow of 200 GPM or more to extinguish. The only definitive guidance on water density requirements for ordnance facilities is Table 5-1, MIL-HDBK 1008. It specifies 0.5 gallons per square foot per minute.

2. An estimate of the maximum flow rate and pressure required by the deluge system should be made to determine water supply requirements. The capabilities of the existing water supply and distribution system to meet these requirements should be evaluated. A minimum static pressure of 45 to 50 pounds per square inch is usually needed at the building. If the required flow rate and pressure are not available, arrangements must be made to provide then. The water pressure required for proper functioning of an ultra high-speed deluge system must be available instantaneously, usually from an elevated tank or pressure tank. The instantaneous flow cannot be produced by starting a fire pump or jockey pump; however, a fire pump can be used to provide the required flow and pressure after the system has started to operate. Response time is directly related to water pressure, the higher the static pressure, the faster the response time. For most applications, the water supply should have a duration of at least 15 minutes. Water supply requirements for other deluge and sprinkler systems must also be considered. Since fires involving munitions are not normally fought, no allowance is required for fire department hose lines. However, the need for hose lines to protect nearby buildings from fires involving class 1.3 and 1.4 material and during cleanup should be considered.

APPENDIX D

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY MATERIEL COMMAND
5001 EISENHOWER AVENUE, ALEXANDRIA, VA 22333-0001

AMC REGULATION
No. 385-100

1 August 1985

Safety

SAFETY MANUAL

12-18. Deluge Systems. a. The deluge system is an instantaneous response (millisecond) ultra-high-speed system controlled by flame detectors (usually ultraviolet or infrared). They are used primarily to protect personnel, process equipment, and buildings from the fire and thermal hazard presented by energetic material involved in high hazard explosive operations such as melting, mixing, blending, screening, sawing, granulating, drying, pressing, extrusion, and pouring. Deluge systems with heat actuated devices (HAD) are not ultra-high-speed deluge systems and should not be used for personnel protection.

b. The design and installation of ultra-high-speed deluge systems for ordnance applications involves a technology which is substantially different from that associated with automatic sprinkler systems. Due to the speed of water delivery from all the nozzles, ultra-high-speed deluge systems are highly dependent on the detection system, piping network, nozzles, and water supply characteristics; the design, specification, and installation of the deluge systems must be performed by experienced designers, engineers, and installers who thoroughly understand the limitations and capabilities of these systems.

c. Sequence of operation. When the flame detector senses a fire within its scanning range, notification that a fire condition exists is sent to the controller. The controller in turn sends an electrical impulse to open the valve. At the same time signals are sent to operate audible and/or visual alarms and to shut down process equipment. The deluge system consists of the following components:

(1) Detector. The most commonly used detector is the flame detector. It is an optical device that responds to the radiant energy that is given off by a flame. When a flame or ignition source occurs within the field of view of the detector, the resulting electromagnetic radiation travels toward the detector at the speed of light. The detector responds to the radiant energy in milliseconds, sending a signal to the electronic controller. Two types of detectors are commonly used in ultra-high-speed deluge systems: ultraviolet and infrared. The ultraviolet (UV) detector senses electromagnetic energy in the UV spectrum and is used primarily to observe open area operations such as ammunition assembly and renovation operations. The infrared detector senses energy in the infrared (IR) spectrum and is used primarily to observe operations in enclosed process equipment. The detectors should be constantly scanning and capable of responding and signaling when a flash or flame is detected. Each detector should have a method for automatically or selective remote verification of optical supervision and cleanliness. Detectors normally have about an 80 degree cone of vision. A third type of sensor is the fast acting (millisecond) pressure sensor. It responds to the pressure generated by a deflagration.

(2) Controller. The controller contains all the electronic circuitry for processing the signal from the detector to actuate the relays that control the deluge valve. The controller should be self-supervising with independent relay contacts, field adjustable sensitivity, plug-in modules and relays, and switches to put the system into a standby or bypass. The controller should have coded readouts of the system faults as they occur displayed prominently on the front panel. The controller should also contain the necessary instrumentation to monitor detectors, energize the audible and/or visual alarms indicating systems activation or malfunction, to transfer these signals to remote designated locations and to automatically stop the process equipment in the affected areas. The control panel should be located where it is easily accessible. A backup electrical power system should be provided. The backup system should be able to meet the electrical requirements of the system for 8 hours and still be capable of activating the deluge system.

(3) Valve. There are two common types of valves used in ultra-high-speed deluge systems. The squib operated valve uses an electrically fired explosive primer to open the valve permitting water to flow. The solenoid activated valve uses an electrically operated solenoid to open a poppet valve releasing pressure from the pilot line which permits the main valve to open and water to flow. A third type of valve is the electrically initiated rupture disc.

(4) Piping. The diameter, length, number of bends, and friction coefficient limits the effective flow rate of water that can be transported at an effective pressure by the piping system. Pipe runs should be kept to a minimum, and all horizontal runs should be sloped at least 1/4 inch per 10 feet of run, with air bleeders at all high points. The looping of deluge piping systems may improve response time by improving pressure and effective flow rate.

(5) Nozzle. The design of the orifice determines the dispersion pattern, water droplets, and turbulence of the water flow which in turn, directly affects the water velocity. Nozzles should be installed with priming water being held back at the nozzle with blowoff caps, rupture disc, or the poppet valve when utilizing pilot operated nozzles. Nozzle discharge rates and spray patterns should be selected to meet the hazard condition being protected.

d. Hazard analysis. All munition production, maintenance, renovation, and demil operations will be subject to hazard analysis in order to identify potential fire and thermal threats and to assess the level of risk. The hazard must be accurately defined. The risk assessment should include factors such as: initiation sensitivity; quantity of material; heat output; burning rate; potential ignition and initiation sources; protection capabilities (operational shields, clothing, etc.); personnel exposure (including respiratory and circulatory damage); munition configuration; process equipment; process layout; and building layout. A potential fire and/or thermal hazard whose level of risk (RAC 1 or 2) is unacceptable will be mitigated by a ultra-high-speed deluge system, unless such a system will aggravate the hazard. (Reference AR 385-10 and AMC-R 385-3).

e. Design. Once the hazard has been accurately defined, the deluge system can be properly designed. The design and installation of ultra-high-speed deluge systems for ordnance applications involves a technology which is substantially different from that associated with automatic sprinkler systems. Ultra-high-speed deluge systems are fire detection and suppression systems capable of water delivery from all nozzles in milliseconds following the detection of a fire. The deluge system is part of the total protection provided for an operation. Other protective features such as clothing, remote operations, protective construction, operational shields, venting, etc., must be considered. Factors such as water pressure, water density, water flow rate, pipe size, number of nozzles, nozzle design (spray pattern), pipe configuration, deluge valve location, water travel distance from nozzle to target detector location, number of detectors, and distance from detector to the hazard must be considered. Where no applicable data exists, experimental fire extinguishment should be performed in a safe location. Nozzles and detectors should be located as close as possible to the exposed energetic material to provide the best possible response time.

f. Performance. The deluge system must be capable of preventing propagation of a fire from the cell or bay to another. In conjunction with personal protective equipment required for workers at the operation, the deluge system shall prevent significant injury to the worker. The workers should not receive more than first-degree burns as the result of any thermal threat. The effectiveness of the deluge system shall be demonstrated by tests against actual or equivalent threat. These tests should be conducted with the maximum quantity of energetic material expected to be in the cell or bay. In lieu of testing, a small deluge system (design flow of 500 GPM or less) shall have a response time of 100 milliseconds and a large deluge system (design flow of more than 500 GPM) shall have a response time of 200 milliseconds or less, provided the hazard analysis indicates that a faster response time is not required. The results of tests or the use of the 100 or 200 milliseconds or less response time will be retained on file by the installation for the life of the system. Response time is defined below.

g. Density. The required density will depend upon the type of energetic material involved, process layout, and whether the aim is extinguishment, prevention of propagation, prevention of serious injury, or a combination of these. A commonly used density for preventing propagation and structural damage is 0.5 GPM/SQ FT. For protection of personnel and process equipment or extinguishment of pyrotechnic materials, significantly higher density rates may be necessary. These may be as high as 3.0 GPM/SQ FT for area coverage or 200 GPM for point of operation coverage.

h. Water supply. An estimate of the maximum flow rate and pressure that would be required by the deluge system should be made. The capabilities of the existing water supply and distribution system to meet these requirements should be evaluated. If the required flow rate and pressure is not adequate, arrangements must be made to provide the required flow and pressure. The water pressure necessary for proper functioning of a deluge system must be available instantaneously, usually from an elevated tank or pressure tank. The instantaneous flow cannot be produced by starting a fire pump; however, a fire pump can be used to provide the required flow and pressure after the system has started to operate. The water supply should have a duration of at least 15 minutes. No allowance is required for hose lines. All valves on water lines between the water main and the deluge systems will be supervised to ensure the valves are not accidently closed.

i. Explosive vapors, gases, or dusts. When explosives vapors, gases, or dusts may enter nozzles and interfere with their operation, nonmetallic internally spring-held caps should be placed on the nozzles. The design must provide immediate release of the cap upon exertion of water pressure with the nozzle. Caps should be attached to the nozzles with small nonferrous chains to prevent their loss in equipment upon activation of the deluge system.

j. Manual activation. The deluge valve should be arranged for automatic and/or manual activation. Manual activation devices should be located at exits, in addition to the requirements of paragraph 5-9, and may be located at the operator's station when the hazard analysis determines the risk to the operator to be acceptable.

k. Response time. It is defined as the time in milliseconds from the presentation of an energy source to the detection system, to the beginning of water flow from the critical nozzle under test. The critical nozzle(s) is usually located closest to the hazard or as determined by a hazard analysis.

l. Measurement of response time. Two methods are commonly used to measure response time.

(1) Digit timer. A millisecond digital timer is started by a saturated UV source (IR for IR detectors) held directly in front of the detector and is stopped by the actuation of a water flow switch at the critical nozzle(s). This method does not measure the time lag of and water travel time from the nozzle to the target. It is normally used for routine testing.

(2) High-speed video recording system. A high-speed video camera and recorder (at least 120 frames/second) can be used as it permits very accurate measurement. The time from ignition to detection and water travel time from nozzle to target can also be measured. The video recording system can be used for contract compliance or when measurement of total response time is required.

m. Testing and maintenance. Deluge systems shall be tested and maintained per the criteria of TM 5-695 and para 12-18k. A good preventive maintenance program is required to reduce the number of false alarms and other system problems. Systems in laid-away or inactive facilities are exempt; however, they will be tested when put back into service. Records of the tests should be kept on file at the installation.

(1) A full operational flow test shall be conducted at interval not to exceed 1 year, including measurement of response time. The results of tests will be retained on file by the installation for the life of the system.

(2) Detectors shall be tested, inspected for physical damage and accumulation of deposits on the lenses at least monthly.

(3) Controllers will be checked at the start of each shift for any faults.

(4) Valves on the water supply line shall be checked at the start of each shift to ensure they are open. Unless the valve is secured in the OPEN position with a locking device or is monitored by a signaling device that will sound a trouble signal at the deluge system control panel or other central location.

n. Melt kettle and closed containers of molten explosives. They will normally not be equipped with internal flame detectors or deluge mozzles for the following reasons: The detector lenses or viewing ports are usually obstructed by molten explosives or moisture; the internal temperature of the kettle or container usually exceeds the maximum operating temperature of flame detectors (typically 150 degrees F.); the adverse and potentially violent reaction of water from leaks and condensation with molten explosives, especially those containing materials such as powdered aluminum and powdered magnesium; and the adverse effect of large quantities of cool water hitting the molten explosives. The exterior of the kettles and closed containers should be protected by ultra-high-speed deluge systems, especially openings where materials are placed in them. The hazard analysis requirements of paragraph 12-18d must be considered.

APPENDIX E

4.4.2 Ordnance Facilities: The choice of fire suppression systems for ordnance facilities shall be based on the following considerations, which are listed in no particular order:

a. Presence/absence of personnel.

b. Exposed/unexposed energetic materials.

c. Period of time exposed energetic materials are present.

d. Process(es) involved.

e. Physical properties of the energetic materials; i.e., rate of pressure rise, rate of decomposition/deflagration/detonation/initiation sensitivity, etc.

f. Potential ignition and initiation sources.

g. Quantities of energetic materials.

h. Suppression goals (considering total extinguishment, prevention of propagation, equipment protection, personnel protection, and building protection).

i. Survivability of the suppression/detection system.

j. Physical properties of nonexplosive materials present; i.e., solvents, flammable liquids, combustible packaging materials.

k. Lessons learned.

l. Not used.

m. Test data.

n. Hazard analysis, safety assessment, and system safety assessment.

o. Building construction.

p. Type of process equipment and layout.

q. Munitions configuration.

r. Frequency of operation.

s. Other protective measures such as clothing, equipment, shielding, and remote operations.

t. Individual DOD service ordnance criteria.

4.4.2.1 Energetic material: Energetic materials includes any chemical compound or mechanical mixture which, when subjected to heat, impact, friction, detonation, or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases which exert pressures in the surrounding medium. The term applies to materials that either detonate or deflagrate and include explosives, propellants, and pyrotechnics. The paragraphs below provide guidance for facilities that contain energetic material. Use of competent engineering judgement is essential. All projects must conform to DOD 6055.9-STD, Ammunition and Explosives Safety Standards; Navy projects shall also conform to NAVSEA OP 5 Volume 1, Ammunition and Explosives Ashore; Army projects shall also conform to AR 385-64, Ammunition and Explosive Safety Standards; and Army Materiel Command projects shall also conform to AMCR 385-100, Safety Manual, and AR 385-64.

4.4.2.2 Ordnance facilities with exposed energetic material: These include ordnance production, assembly, maintenance, and surveillance facilities containing exposed energetic material. Typical procedures performed on exposed energetic materials (explosives, propellants, and pyrotechnics) include, but are not limited to: magnetic separation, visual inspection, screening, melting, machining, pressing, rocket motor assembly, projectile loading, drilling, defuzing, thread cleaning, propelling charge assembly, pouring, booster loading, blending, weighing, drying, mixing, grinding, pelletizing, igniter assembly, fuze assembly, depriming, flaking, washout/steamout, extrusion, casting, sawing, and granulating. Complete protection of such facilities is essential. Specific automatic sprinkler protection requirements for areas within these type of facilities are as follows:

a. Ultra-high-speed deluge systems are preprimed instantaneous response ultra-high-speed systems controlled by flame detectors which start to deliver water in milliseconds (ms). They are used primarily to protect personnel, process equipment, and buildings from the fire and thermal hazard presented by exposed energetic materials involved in ordnance operations and storage. Deluge systems with HADs (heat actuated devices) are not ultra high speed deluge systems due to their slow response times of 20 to 100 seconds. They provide little personnel protection. Refer to Table 10 in section 5, Water Demands for Sprinklered Facilities under the occupancy classification "Ordnance Plants (exposed energetic material)" to determine the sprinkler design criteria.

b. The design and installation of ultra-high-speed deluge systems for ordnance applications involves a technology which is substantially different from that associated with automatic sprinkler systems. Due to the speed of water delivery from all the nozzles, ultra-high-speed deluge systems are highly dependent on the detection system, piping network, nozzles, and water supply characteristics; the design, specifications, and installation of ultra-high-speed deluge systems must be performed by experienced designers, engineers, and installers who thoroughly understand the limitations and capabilities of these systems.

c. Sequence of operation. When the flame detector senses a fire within its scanning range, notification that a fire condition exists is sent to the controller. The controller in turns sends an electrical impulse to open the valve. At the same time signals are sent to operate audible and/or visual alarms and to shut down process equipment. The deluge system consists of the following components:

(1) Detectors - The most commonly used sensor is the flame detector, either ultraviolet (UV) or infrared (IR) is the flame detector. It is an optical device that responses to the radiant energy that is given off by a flame. Two types of detectors are commonly used in high-speed deluge systems. When a flame or ignition source occurs within the field of view of the detector, the resulting electromagnetic radiation travels toward the detector at the speed of light. The detector responds to the radiant energy and sends a signal to the electronic controller when the sensing threshold of the detector is reached. The UV detector senses electromagnetic energy in the UV spectrum. UV detectors are normally used to provide area coverage over and around process equipment. At least two detectors are normally used - one to cover the specific hazard and one to cover the bay. The IR detector senses electromagnetic energy in the IR spectrum. IR detectors are normally used in closed process equipment, vessels, and covered conveyors shielded from natural and artificial light. The detectors should be constant scanning and capable of responding and signaling when a flash or flame is detected. Each detector should have a method for automatically or selective remote verification of optical supervision and cleanliness. Detectors normally have about an 80-degree cone of vision. A third type of sensor is the fast acting (ms) pressure sensor. It responds to the pressure generated by a deflagration. Heat detectors are recommended for ordinary deluge systems. Smoke detectors are not usually used for ordnance facilities detection/suppression system. An exception to this is facilities that handle or process munitions containing smoke mixes, when the smoke could blind UV and IR detectors and a ms response time is not required.

(2) Controller - The controller contains all the electronic circuitry for processing the signal from the detector to actuate the relays that operate the deluge valve and other related outputs. The controller should be self-supervising with independent relay contacts, field adjustable sensitivity, plug-in modules and relays, and switches to put the system into a standby or by-pass. The control panel/rack assembly should have read-outs of the system faults as they occur displayed prominently on the front panel. The assembled panel/racks should also contain the necessary instrumentation to monitor detectors, controllers and flow control components, to energize the audible and/or visual alarms indicating system activation or malfunction, to transfer these signals to remote designated locations (fire department etc.) and to automatically stop the process equipment in the affected areas. The control panel should be located where it is easily accessible. A backup electrical power system should be provided. The backup system should be able to meet the electrical requirements of the system for 24 hours.

(3) Valve - There are two common types of valves used for high speed deluge systems. The squib operated valve uses an electrically fire explosive primer to open the valve permitting water to flow. The solenoid activated valve uses an electrically operated solenoid to open a poppet valve releasing pressure from the pilot line which permits the main valve to open and water to flow. A third type of valve is the electrically initiated rupture valve.

(4) Piping - The diameter, length, number of bends, and friction coefficient contribute to the volume of water that can be transported at an effective pressure by the piping system. Pipe runs should be kept to a minimum, and all horizontal runs should be sloped at least 3/4 inch per 10 feet of run, with air bleeders at all high points. Removal of all trapped air is very important. A very small air pocket can significantly increase response time.

(5) Nozzle - The design of the orifice determines the dispersion pattern, water droplets, and turbulence of the water flow which in turn, directly effects the water velocity. Nozzles should be installed with priming water being held back at the nozzle with blow-off caps, rupture disc or the nozzle poppet when utilizing pilot operated nozzles. Nozzle discharge rates and spray patterns should be designed to meet the hazard condition being protected. Nozzles should be located as close at the hazard as possible, but still protect the operator and all exposed energetic material.

d. Hazard analysis. All munition production, maintenance, renovation, and demil operations will be subject to hazard analysis or safety assessment in order to identify potential fire and thermal threats and to assess the level of risk. The hazard must be accurately defined. The risk assessment should include factors such as: initiation sensitivity; quantity of material; heat output; burning rate; potential ignition and initiation sources; protection capabilities (operational shields, clothing, etc.); personnel exposure (including respiratory and circulatory damage); munition configuration; process equipment; process layout; and building layout. A potential fire and/or thermal hazard whose level of risk is unacceptable will be mitigated by a high speed deluge system, unless such a system will aggravate the hazard.

e. Hazard. Once the hazard has been accurately defined, the deluge system can be properly designed. The deluge system is part of the total protection provided for an operation. Other protective features, such as clothing, remote operations, protective construction, operational shields, venting ect., must be considered. Factors, such as water pressure, water density, water flow rate, pipe size, number of nozzles, nozzle design(spray pattern), pipe configuration, deluge valve location, water travel distance from nozzle to target detector location, number of detectors, and distance from detector to the hazard must also be considered. Where no applicable data exists, experimental fire extinguishment should be performed in a safe location. Nozzles and detectors should be located as close as possible to the exposed energetic material to provide the best possible response time.

f. Performance. The deluge system must be capable of preventing propagation of a fire from the cell or bay to another. In conjunctions with personal protective equipment required for workers at the operation, the deluge system shall prevent significant injury to the worker. The workers should not receive more than first degree burns as the results of any thermal threat. Heat flux that an operator is exposed to should not exceed 0.3 calories per square centimeter per second with the operator wearing the proper protective clothing/equipment and taking turning-evasive action. The effectiveness of the deluge system shall be demonstrated by tests against actual or equivalent threat. These tests should be conducted with the maximum quantity of energetic material expected to be in the cell or bay. In lieu of testing, a small deluge system (design flow rate of 500 gpm or less) shall have a response time of 100 ms and a large deluge system (design flow rate of more than 500 gpm) shall have a response time of 200 ms.

g. Density. The required density will depend on the type of energetic material involved, process layout, and whether the aim is extinguishment, prevention of propagation, prevention of serious injury, or a combination of these. A commonly used density for preventing propagation and structural damage is 0.5 gpm/sq ft. For protection of personnel and process equipment, or extinguishment of pyrotechnic materials, significantly higher density rates may be necessary. These may be as high 3.0 gpm/sq ft for area coverage or 200 gpm for point of operation coverage.

h. Water supply. An estimate of the maximum flow rate and pressure that would be required by the deluge system should be made. The capabilities of the existing water supply and distribution system to meet these requirements should evaluated. If the required flow rate and pressure is not adequate, arrangements must be made to provide the required flow and pressure. A minimum static pressure of 45 to 50 psi is usually needed at the base of the riser. The water pressure necessary for proper functioning of a deluge system must be available instantaneously, usually from an elevated tank or pressure tank. The instantaneous flow cannot normally be produced by starting a fire pump, however a fire pump can be used to provide the required flow and pressure after the system has started to operate. The water supply Shall be adequate to supply the total demand of the largest fire area at the specific residual pressure required by the system(s) plus an allowance for hose stream demand for a period of thirty minutes.

i. Explosive vapors, gases or dusts. When explosives, vapors, gases or dusts may enter nozzles and interfere with their operation, nonmetallic internally spring-held caps should be placed on the nozzles. The design must provide immediate release of the cap upon exertion of water pressure within the nozzle. Caps should be attached to the nozzles with small nonferrous chains to prevent their loss in equipment upon actuation of the deluge system.

j. Manual activation. The deluge valve should be arranged for automatic and/or manual actuation. Manual activation devices should be located at the exits, and may be located at the operators stations when the hazard analysis determines the risk to the operator to be acceptable.

k. Response time. It is defined as the time from the sensing of a detectable event by the detector to the beginning of water flow from the critical nozzle(s) closest to the target. This will normally be the nozzle(s) closest to the hazard or as determined by the hazard analysis. While the water travel time from the nozzle to the target is not included in the definition of response time, it must be considered in the design of ultra-high-speed deluge systems.

l. Not used.

m. Measurement of response time. Two methods are commonly used to measure response time.

(1) Digital timer - A ms digital timer is started by a saturated UV (IR source for IR detectors) held directly in front of the detector and is stopped by the actuation of a waterflow switch at the critical nozzle(s). This method does not measure the time lag from actual ignition to detector input and water travel time the nozzle to the target. It is well suited for routine measurement of response time by facility maintenance personnel. It is inexpensive, easy to operate, and quick to set up and tear down.

(2) High-speed video recording system - A high-speed video camera and recorder (at least 100 frames/second) is can used. It permits very accurate measurement. The time from ignition to detection and water travel time from nozzle to target can also be measured. It is used for determining compliance with specifications, system performance after major modifications, and research.

n. Testing. Deluge systems shall be tested IAW the criteria of the tri-service manual Maintenance of Fire Protection Systems (Army TM 5-695; Air Force AFM 91-37; and Navy NAVFAC MO-117). Systems in layed-away or inactive facilities are exempt, however they will be tested when put back into service. Records of the tests should be kept on file at the installation for the life of the system.

(1) A full operational flow test shall be conducted at intervals not to exceed 1 year, including measurement of response time.

(2) Detectors shall be inspected monthly for physical damage and accumulation of deposits on the lenses.

(3) Controllers will be checked at the start of each shift for any fault readings.

o. Ordinary deluge systems shall be provided in other areas or auxiliary sections of buildings which are not properly separated by fire-rated partitions (minimum 1 hour) from areas where exposed energetic material are routinely processed or stored exposed overnight. Refer to Table 10 in section 5, Water Demands for Sprinklered Facilities under occupancy classification "Ordinary Hazard Group 3" to determine the sprinkler design criteria.

p. Wet-pipe (dry-pipe in freezing areas) sprinkler systems shall be provided in other areas or auxiliary sections of buildings which are properly separated by fire rated partitions (minimum 1 hour) from areas where energetic materials are routinely processed or are stored exposed overnight. Such systems will also be provided where encased or enclosed energetic materials (not exposed) and munitions items are stored overnight in production, assembly maintenance, and surveillance facilities. Refer to Table 10, section 5, Water Demands for Sprinklered Facilities under the occupancy classification "Ordinary Hazard Group 3" to determine the sprinkler design criteria.

q. All electrical equipment, including fire detection and fire suppression equipment, in ordnance facilities shall be of the proper explosion classification. All electrical equipment, including fire detection and suppression equipment, in areas protected by deluge systems shall be suitable for wet locations.

r. Provide complete supervision of all sprinkler and detection systems so that any deficiency that developsthat would affect the speed or reliability of operations will provide a distinctive alarm.

4.4.2.3 Melting Kettles: Melting units, melt-mix kettles and other equipment containing reservoirs of molten explosives shall be equipped with water deluge systems designed to completely and rapidly flood the equipment. The portions of the suppression piping within the equipment shall not be pre-primed with water and shall be protected by nonferrous or nonmetallic caps which will rupture or blow off and allow the water to flow. The valve shall be located outside the equipment and a weep hole shall be provided near the valve to guard against accidental leakage into the pipe. A 1-1/4 inch pipe under a head of at least 40 psi is recommended. The system shall be provided with automatic and manual activation. Detection devices (usually UV or IR detectors) shall be located to look into the interior of the kettle or reservoir during operation of the equipment. If a hazard analysis indicated detection is required only around the exterior the kettle or reservoir, then interior detection is not require.

4.4.2.4 Ordnance facilities with contained or encased energetic material: These include ordnance production, assembly, maintenance, and surveillance facilities with energetic material that is contained or completely encased in torpedo warheads, missile warheads, mines, rocket motors, projectiles, full up rounds (torpedo, missile, projectiles etc), and bulk energetic materials in fire resistant containers (e.g. metal but not fiberboard containers). Typical operations include but are not limited to: missile, torpedo, and projectile assembly, inspection, inprocess storage, laboratories, and packout. Specific automatic sprinkler protection requirements for areas within these type of facilities are as follows:

a. Wet-pipe (dry-pipe in freezing areas) or pre-action sprinkler systems are required. If electronic equipment is present, pre-action sprinkler systems are recommended. Refer to Table 10 in section 5, Water Demands for Sprinklered Facilities under the occupancy classification "Missile Assembly" to determine the sprinkler criteria.

b. Complete protection of such facilities is essential.

4.4.2.5 Test Cells: Missile and other weapon test cells shall conform to the requirements above for Explosive Operating/Assembly Buildings except that ordinary deluge systems (pre-primed or not pre-primed) should be installed in test cells if a rapid-spreading fire can be expected to occur as a result of a design basic accident. Exit doors shall be manually openable without requiring electric power.

4.4.2.6 Storage magazines: When constructed in accordance with definitive designs and used only for storage, storage magazines do not require automatic sprinkler protection.

4.4.2.7 Shipping/Receiving/Transfer/Handling/Segregation Facilities: In these facilities there should be no exposed energetic material, only finished ordnance items or energetic material that is total encased in project bodies, shipping containers, drums or boxes. They may remain in the facility overnight or short periods of time awaiting shipment. Refer to Table 10, in section 5, Water Demand for Sprinklered Facilities under the occupancy classification "Ordinary Hazard Group 3" to determine the sprinkler design criteria.

4.4.2.8 Automatic sprinkler and deluge systems in ordnance facilities shall be provided with flexible couplings and sway bracing similar to that provided for buildings in earthquake zones.

4.4.2.9 Ordnance facilities shall be provided with panic exiting hardware for personnel doors.

4.4.2.10 The provision of floor drainage should be considered for ordnance facilities protected by deluge systems. The run off water may be contaminated with explosive waste. This must be considered in the system design.